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Dust Control on Longwall Faces by Fine Mist (Atomising) Sprays - Can They Really Work?

I. McDonell

DUST CONTROL ON LONGWALL FACES BY FINE MIST (ATOMISING) SPRAYS - CAN THEY REALLY WORK?

Ian McDonell[1]

ABSTRACT: The ongoing efforts to suppress dust emissions from longwall face shearing and transporting operations have met with varying degrees of success. A particular of concern has been the thicker, gas drained seams where both respirable and combustible fallout dust production has not always met with successful suppression methods using water spray system. There are current programs planning to use very fine atomising sprays that give a water droplet size approaching the respirable dust particle size, and mines are waiting to see how well these systems will work. ***S***ome peripheral science such as fluid mechanics and aerodynamics are discussed to determine whether other factors are present that may inhibit the ability of water spray systems to successfully reduce fine dust emissions to acceptable levels.

It appears from the initial investigation that water droplets cannot capture all the dust particles generated during coaling operations, and that chemical additives to the spray water may also be limited in their success. The paper also looks at possible methods to better suppress dust, and suggests that far more research and engineering may be warranted. In particular the risks from use of ultra fine water droplets for longwall dust suppression may in fact have health risks that outweigh any potential benefits.

INTRODUCTION

Since the introduction of high productivity longwalls, particularly in thick seams that have been gas drained, respirable dust suppression has been a challenge not always met with success. Many mines still suffer dust sampling results that are close to or in excess of statutory limits, despite ongoing (and expensive) attempts to improve those results.

By way of relating some scientific reasoning with observations made over many years, the author proposes that there are reasons for the ongoing challenges that are not purely mining related, and further suggests that proposals to implement fine mist (atomising) water sprays as an improved dust mitigation strategy may be flawed. While significant research has been undertaken over many years in this area, the author contends that some further work in basic science may be warranted to justify the significant expense of some of the high level engineering dust control systems that are being considered for use.

THE TRIGGER FOR SCIENTIFIC ANALYSIS

People who regularly fly out of capital cities frequently notice the surface atmospheric dust level. This is the yellow brown, fine visible dust that hangs in the air to levels sometimes exceeding three thousand meters or to the base of cloud on other occasions.

Figure 1 shows typical visible dust layer over a city shown from an aircraft.

Figure 2 shows a wing leading edge of a five year old aircraft with no visible paint damage from dust erosion. It is fair to question as why this fine dust did not remove paint work from the leading edges of an aircraft, given that it would certainly be abrasive enough to do so. A research into aerodynamics and the boundary layer effects, a well known phenomenon in aircraft design since World War 2, has provided the answer. A boundary layer is created around an object passing through air by the surface resistance of the shape to the passage of the airflow. The boundary layer can be considered to be the

[1] *1 Pintail Street North Lakes, Queensland 4509*

Figure 1 – Typical visible dust layer over a city shown from an aircraft (Airliners.net website 2008)

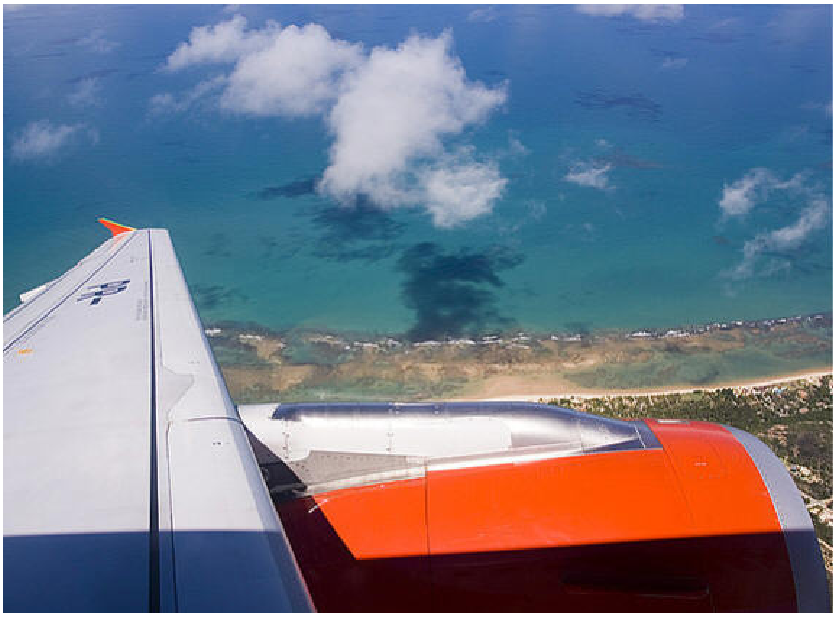

Figure 2 – Leading edge of an aeroplane wing showing no paint wear (Airliners.net website, 2008)

transition from still air at the surface of the object, to the area of full air flow where the surface resistance has no further effect, as shown in Figure 3 (John Glenn Research Centre of NASA, undated). Boundary layers have been proven in wind tunnel testing, and many attempts to break down the layer have been made over the years, as it is believed that reducing the layer will increase lift on an airfoil while reducing drag, leading to improved aircraft performance. Some success was been recorded but no quantum leap forward to date.

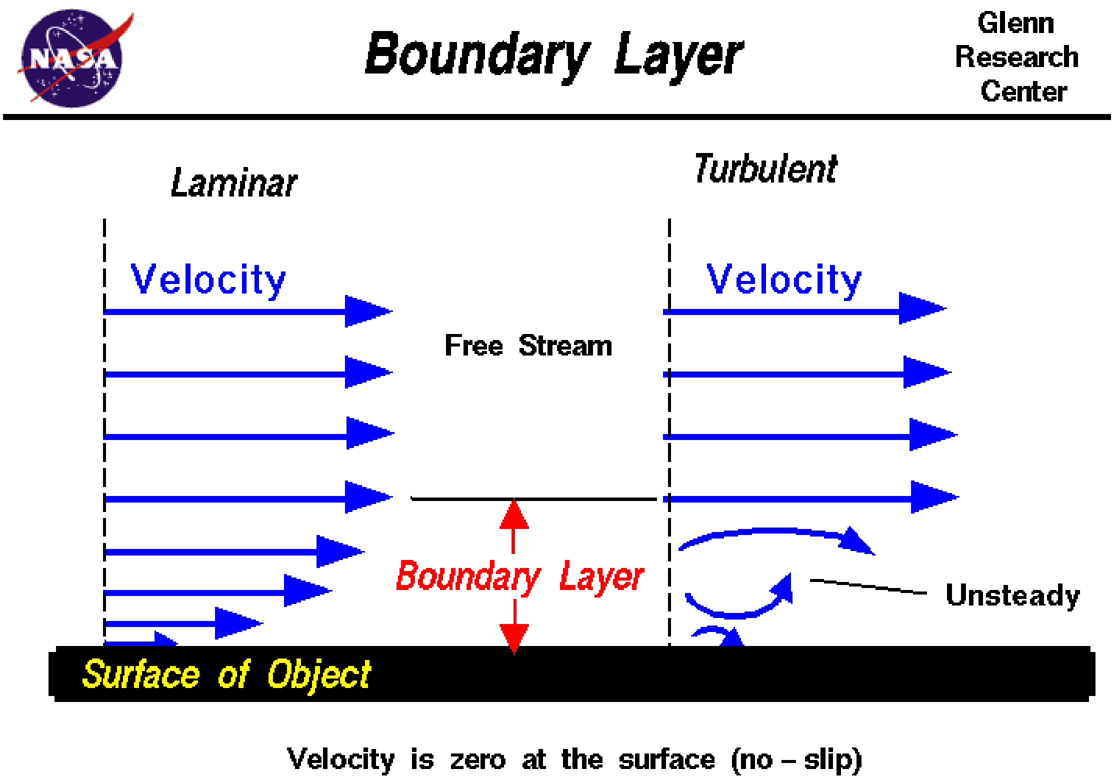

Figure 3 – The boundary layer above an object's surface in airflow (NASA)

It is the author's belief that a boundary layer exists around dust particles in the airflow along longwall faces, and the net effect of this layer is to make collisions between dust particles and water droplets, essential for suppression of dust, all but practically impossible where the air flow is laminar and not turbulent. The remainder of this paper addresses these matters. This paper does not offer practical working solutions as the base hypothesis has not been tested; however suggestions for further work are included. The effect of the layer is shown in Figure 4 (Ian McDonell, 2008); where the smaller dust particles are carried past the water droplet with little chance of collision.

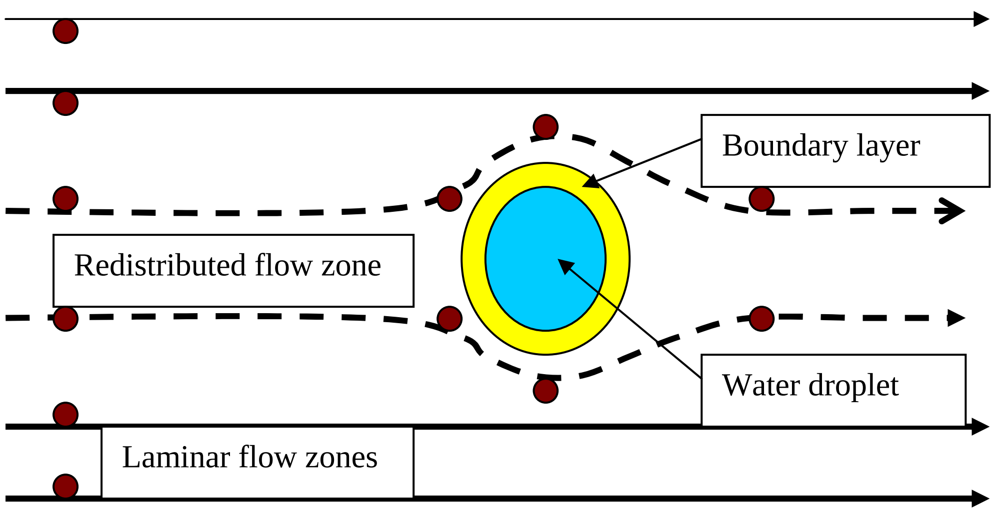

Figure 4 – The redistribution of laminar airflow around the boundary layer (After "Beginners guide to Aeronautics", NASA website, undated

LONGWALL DUST CONCEPTS

It is important to note the following particle size comparisons for dust and water droplets as applied to a longwall face.

- Visible dust is normally considered to be larger that 100 microns in size
- Respirable dust as defined in legislation is that fraction less than 10 microns, and is considered hazardous particularly when less than 4 microns when it can be deposited into the gas exchange regions of the lungs. It has a sub-division called "thoracic", being the particle range 4 to 10 micron, which is stated to be hazardous when deposited in the lung airways.
- Inhalable dust is defined as the fraction that is less than 100 microns, and is stated to be hazardous as it can deposit anywhere in the head airway region (from AS2985, AS3640 and "Personal Multi-fraction and Bio-aerosol sampling" by Weber Consulting Website.)
- Water mist and droplets as produced by typical longwall sprays is formed in the size range from 100 to 5000 microns (Spray data from "Engineer's Guide to Spray Technology", bulletin number 498 from Spraying Systems Co. Illinois, USA, undated)
- 1000 microns is 1 mm
- The full stop of 12 point Times New Roman print is about 250 microns.
- It should also be noted that for the common hollow cone spray used for dust suppression, and operated at 700 Pa (100 psi) at a flow of 3 litres per second (30 g.p.h.), an average droplet size of 1260 microns is produced. (Spray data from "Engineer's Guide to Spray Technology", bulletin number 498 from Spraying Systems Co. Illinois, USA, undated)
- To reduce this to an average size of 200 microns, getting near to dust particle size, an air atomising spray operating at 70 Pa (10 psi) and 0.0015 litres per second (0.02 g.p.h.) is required. (Spray data from "Engineer's Guide to Spray Technology", bulletin number 498 from Spraying Systems Co. Illinois, USA, undated)

MINING LEGISLATION REGARDING DUST

Both NSW and Queensland legislation sets limits of total dust content in the respirable range including limits for quartz. The legislation also requires management plans for control of airborne dust including regular sampling of respirable dust and quartz. Recent changes to NSW legislation also require sampling for inhalable dust. It is likely that tighter controls will be implemented over time, and particularly if mines register results around or over the statutory limits. There are two Australian Standards regarding dust:

1. AS2985-2004 "Workplace Atmospheres – Method for sampling and gravimetric determination of respirable dust"
2. AS3640 "Workplace atmospheres - Method for sampling and gravimetric determination of inhalable dust

DUST SUPPRESSION BY WATER DROPLETS

Suppression dust by water droplets in a moving airstream requires impacts between the dust and droplets. By impacting, the dust adheres to the droplet, falling under gravity to floor level. Conventional logic suggests that a higher quantity of finer water droplets will suppress the dust better. This is not often backed up by actual data, but inconsistencies in data collection may hinder the true analysis.

Around the shearer drums, and in the outbye shearer clearer zone, turbulence is created in such magnitude so as to be a credible factor in creating these impacts. The maingate to face corner should also have a certain amount of turbulence that can be used with sprays to remove both incoming dust and dust created by the longwall from such sources as the shearer at the maingate, coal breakage on the chain and from the movement of the shields. The face to tailgate corner is similar to the maingate end in this respect.

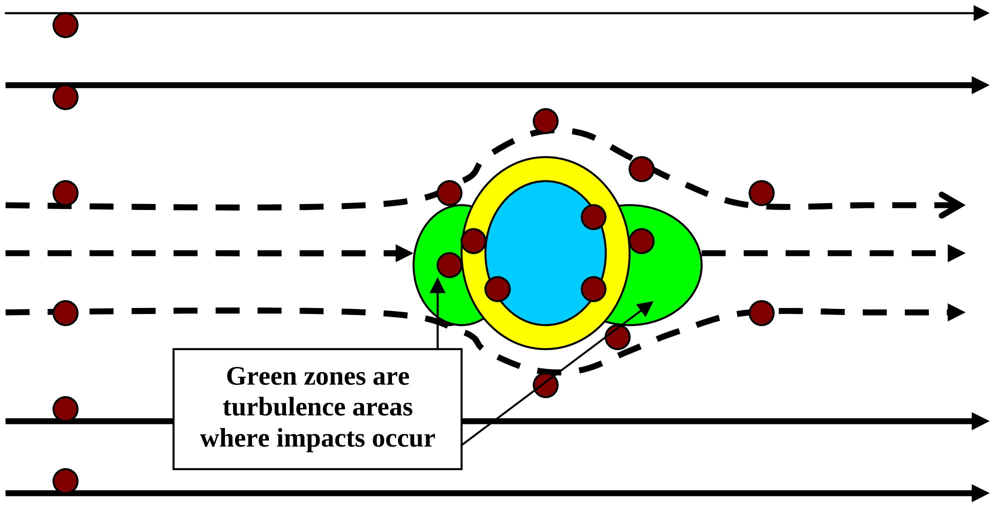

Figure 5 – The turbulent areas around a water drop where impacts may occur (After "Beginners guide to Aeronautics", NASA website, undated)

From the previous redistribution diagram, Figure 5 shows the zones of turbulence that are known to occur when airflow passes over an airfoil. The rear turbulence zone is much stronger than the frontal one, but due to the airstream velocity effect, more impacts are likely at the front. This diagram only applies to laminar flow areas, where I believe a minimum of impacts occur. In a longwall environment, the large majority of impacts only happen in the extremely turbulent zones around the drums and clearers.
The balance of the face, that is from maingate to shearer, and from shearer to tailgate, and tailgate corner outbye are all zones of laminar airflow, and as such may rely more on luck for impacts rather than turbulence. In all probability, dust suppression in these areas could only occur if additional turbulence is introduced, for example by way of deflection curtains and spray systems.

Full mine testing has shown that a significant amount of respirable dust particles travel extensive distances out the return airways (Gillies and Wu, 2008), and only appear to fall out of the airflow when the airspeed drops considerably or it goes around sharp, higher resistance corners. This has been tested at several mines by Gillies, and Wu, (2008).

USE OF WATER SURFACE TENSION AND STATIC CHARGE MODIFIERS

Surface tension modifiers are designed to allow the droplets to take other shapes than the pure sphere, which under equilibrium conditions is the lowest energy state. In a laminar airflow, the effect will be to elongate the droplet while reducing the frontal surface area. The amount of elongation and consequent decrease in frontal surface area will depend on the surfactant properties of the additive, its strength and the velocity of the airflow. This will certainly result in much smaller turbulent zones in front and behind the droplets, making random collisions between dust and water even more remote, as shown in figure 6.

Any beneficial effects of surfactant will be felt more in the highest turbulence areas, where the airflow effect is less than in laminar flow areas.

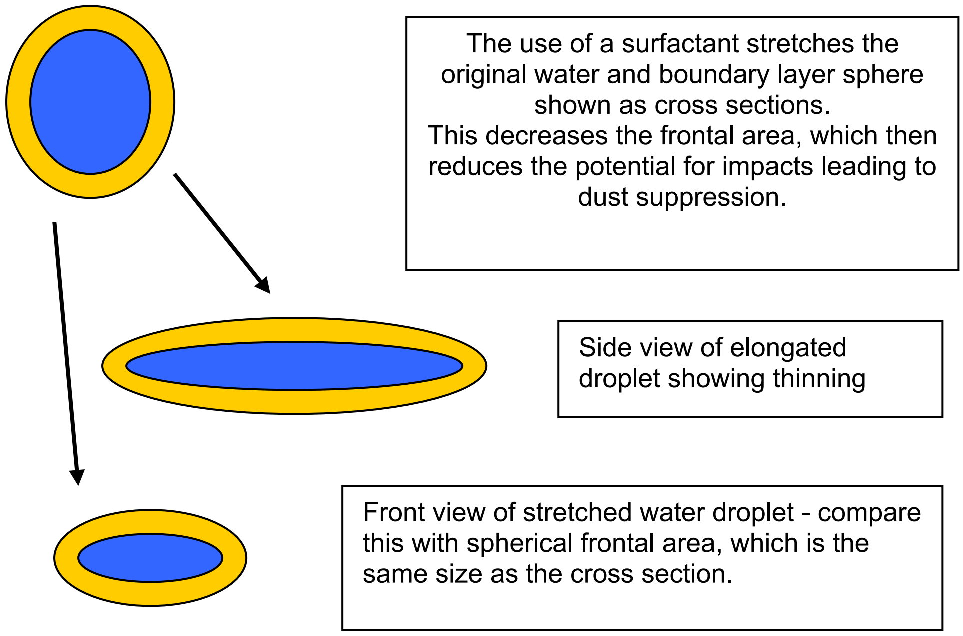

Figure 6 – The effect of surfactant on a water droplet in airflow

Water and dust particles in airflow will be affected by static electricity charge pick up. The intensity and polarity of the charge will vary depending on factors such as dust material type and size range (rubbing surface), water purity including acidity or alkalinity, water droplet size, velocity of airflow and effect of electromagnetic radiation from cables and motors. The rubbing surface is probably the biggest variable giving a likely result that the charge on small dust particles is quite low compared to the much larger water particles. The net effect is possibly not able to be accurately modelled, and so selection of a suitable static charge modifier may be difficult. It would also at this time be difficult to predict whether or not smaller water droplets would assist or hamper electrostatic attraction.
The object of a static charge modifier added to the water (be it anionic or cationic) is to impart opposite change in the water to that of the dust, causing electrostatic attraction and hence collision / capture. The author believes that this process has a long way to go before it can be demonstrated as successful.

Major fine dust producers such as coal fired power stations frequently use electrostatic dust precipitators, which use very high voltages across metallic plates to polarise and attract the dust. There is no possibility of using this technology underground.

EFFECT OF WATER AND GAS DRAINAGE FROM COAL ON DUST PROPERTIES

Gas drainage from coal whether methane or carbon dioxide is usually accompanied by large volume of water, which then allows shrinkage and drying out of the coal matrix. This directly contributes to the dust concentration when the coal is mined, but may have other outcomes dependant on the actual make up of the coal. Personal observations over many years have noted that some types of coal are very difficult to wet after the drainage process.
It has been suggested in discussion between coal chemists and geologists that this may be caused by a very fine "oily" film forming on the coal particles after drainage. While this is anecdotal only, it certainly could explain why added water sprays even around the shearer drums and clearers do not get the desired dust suppression effect.

DUST MEASUREMENT

The majority of dust sampling to date has been done with cyclone separation and collection of the sized particles for weighing, generally over the period of a full shift. This gives an accurate figure for the total dust exposure for the period sampled, but cannot be related to any actual longwall operation such as position of shearer on face. Further, standard sampling does not always accurately reflect the source, quantity and timing of respirable dust entering the longwall from outbye. This further detracts from the value of measurements done to test control measures.

The author believes that for most operations, there is a need to use the newer real-time dust sampling tools available combined with a comprehensive test program that relates mine external as well as longwall dust sources to the longwall operations. For example respirable and inhalable dust reporting to the longwall may enter the mine airstream from the surface, from belt systems and travelling roads and from machinery.

CREATING MORE DUST TO WATER DROPLET IMPACTS AND IMPROVING COLLECTION OF DUST

Table 1 shows concepts that are considered by the author to be potential ways to enhance suppression, and are given along with potential weaknesses. The list is not exhaustive.

Table 1 – Details of methods to improve the number of dust to water droplet impacts

Concept	Method	Weaknesses
Reduced size of water droplets	Air / water atomising sprays	Vastly decreased water flow rates Much larger number of sprays for motor cooling flow
Increased size of dust particles but less fracture of the coal and rock	Modified cutting picks Modified drums, lacing, flights Slower drum speeds Slower chain speeds Modified lump breaker	Reduced output of shearer Potential blockages from larger lump sizes
Increased turbulent zones	Airflow deflectors Air blowers	Damage to equipment from face spalling and impacting with the shearer and shields
Modified turbulent zones	Use of cowls to contain zone Shrouding around shearer and clearers	Damage to cowls and shrouds
Machine mounted dust scrubbers	Use of rotary air curtain drums, with or without extraction Use of shearer mounted scrubbers	Cost versus effectiveness
Antitropal versus homotropal air flow for shearer clearer areas. Maingate clearer is Antitropal whereas tailgate is homotropal, with reduced effect	Modification of design to address.	Size and power usage Unproven exercise would be very costly.

HEALTH AND SAFETY CONSIDERATIONS

The use of ultra fine water mist sprays for dust suppressions is not without concerns in the health and safety area. The amount of additional fine water vapour may have the effect of more rapidly blocking filters used in air helmets and filter masks. This may result in more frequent changes of disposable masks – not a bad thing – or the temptation not to wear them.
Early blockage of air helmets leads to discomfort for people using them, and again tempts them to remove the PPE.

A further consideration is that by reducing the droplet size to an inhalable or respirable size will allow some of the water to enter the breathing zones of the body. The effect of this is not documented, but will need some medical considerations.

CONCLUSIONS

From my experience, observations and limited research I have made the following (highly arguable) conclusions:

1. Results of fine dust measurements as a result of changes made in an attempt to enhance dust suppression on longwall faces (particularly thicker seams) have not always shown effectiveness of the changes.
2. Reasons for this variation may be because the testing is not suitably comprehensive or relatable to the changes due to shift duration aggregate tests versus real time tests.
3. There may be many other scientific reasons for lack of effectiveness of longwall dust suppression that could be based on fluid mechanics and aerodynamic principles.
4. The use of fine atomising air / water sprays may not be effective when trialled due to these other effects.
5. There is an opportunity for specialised research into some of these matters that could lead to major improvements.
6. There is a lot of work in risk management to be done, both from the safety and health and operational points of view.

ACKNOWLEDGMENT

This paper is the work of the author, and any referred material that may be subject to copyright is acknowledged. The views expressed in this paper are those of the author, and do not purport to have any relationship to any coal mining operation, operator or mining company.

REFERENCES AND OTHERS

1. Photos are from the website cited from "Airliners.net".
2. Boundary layer drawing is from the John Glenn Research Centre of NASA
3. Spray data from "Engineer's Guide to Spray Technology", bulletin number 498 from Spraying Systems Co. Illinois, USA
4. Various references including AS2985, AS3640 and "Personal Multi-fraction and Bio-aerosol sampling" by Weber Consulting (Website).
5. Gillies-Wu Mining Technology, 1 Swann Road Taringa 4068.